Impact of Mid-Blend (>E10) Ethanols as Motor Fuels

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NACAA Fall Membership Meeting
San Diego, CA

October 29, 2007

Topics

- Introduction
- Diversity of Affected Equipment
- Key Properties of Ethanol-Gasoline Mixtures
- Failure Modes
  - With Air Emissions Impacts
  - Others
- Conclusions

Introduction

- Current motor gasolines contain 0-10% by volume ethanol (E0-E10)
- E85 is also available for Flexible Fuel Vehicles (automobiles)
- Driven by many concerns and opportunities, there is significant effort underway at increasing the ethanol content to higher than 10% - such as 20, 30 or even higher percentages.

Introduction (contd.)

- So, what is the problem? Supply-related and production-related concerns aside, this paper will focus on some of the potential problematic areas if >E10 becomes a requirement
- Issues related to transportation, storage, combustion and emissions will be discussed

Diversity of Equipment

- Fuel/Equipment have to be considered together as a system
- Any change in fuel will affect existing equipment
- Roughly 300+ million pieces of equipment will be affected
  - 200+ million automobiles
  - 100+ million off-road equipment

Product (Use) Diversity

- Automobiles
- Motorcycles
- Boats and Marine
- Lawn and Garden
- Snow equipment
- Construction equipment

Product Requirements

- Has to meet
  - Performance
  - Emissions
  - Safety
- Manufacturers want satisfied customers
- Regulators want satisfied customers

Diversity - Conclusion

- Rough cost of existing equipment that will be affected ~ > $2,000,000,000,000.
- Every American household potentially affected
  - Potent political issue

Engine Diversity

- Size: 20 cc to 6000+ cc
- Useful Life: 50 hours to 10,000 hours
- Engine Design
  - Air or Water Cooled
  - 2-Stroke, 4-Stroke, many variations
  - Side valve, over-head valve
  - Variable valve timing
  - Intake air charging – supercharging, turbocharging

Engine Diversity (contd.)

- Fuel Introduction Strategies
  - Carbureted (various types)
  - Fuel Injection
- “Control” Technologies
  - Open loop
  - Closed loop
- Exhaust emissions control strategies
  - Engine modifications
  - 3-way and oxidation catalysts

Fuel System Diversity

- Wide variety of tank and hose materials
- Different evaporative control strategies
  - Permeation reduction, tank venting, etc.
- Multi-positional operational requirements
- Storage-stability issues due to seasonal usage
- Safety constraints

Evaporative System Materials Diversity

Fuel Tanks made of:

- Metal
- HDPE
- Barrier Treated HDPE (fluorinated, sulfonated)
- Selar
- Nylons (various grades)
- Coextruded (various types)
- Other materials

- Fuel Hoses made of:
  - NBR
  - FKM
  - Other materials

What is E20?

- No specification currently available for E20 (or Ex, where x = 11-69)
- E10 and E85 have specifications
- All current tests using E20 rely on experimenters creating their own E20 fuel

What Should E20 (or Ex) Specification Contain

- Ethanol should meet ASTM 4806
- Fuel as a whole should meet ASTM 4814
- Additional denatured ethanol standards (presumably like CA) may need to be met
- Specific denaturant specifications may need to be met (presumably like CA)
- Additives should be specified: ignition improvers, detergents, corrosion inhibitors, anti-foaming agents, demulsifiers, lubricity additives, biocides, etc.
- Finally, certain additional specs (RVP, Distillation curve, Octane No.) will need to be defined

Ethanol Impacts on Fuel Properties

- Octane number
- Volatility
  - vapor pressure
  - Vapor Liquid ratio
  - Distillation curve
- Energy density
- Enleanment
- Water solubility and phase separation

Fuel Property Impacts (Contd.)

- (In)compatibility with materials and parts
  - Metals
  - Rubbers
  - Elastomers
  - Polymers
  - Monomers
- Viscosity
- Factors: Concentration, temperature, altitude, base fuel composition

Failure Modes - 1

- Enleanment causes hotter temperatures and higher cylinder pressures
  - blown head gaskets
  - burnt valves
  - burnt oil
  - loss of head bolt torque
  - damage to catalysts

Gasket Failure Consequence

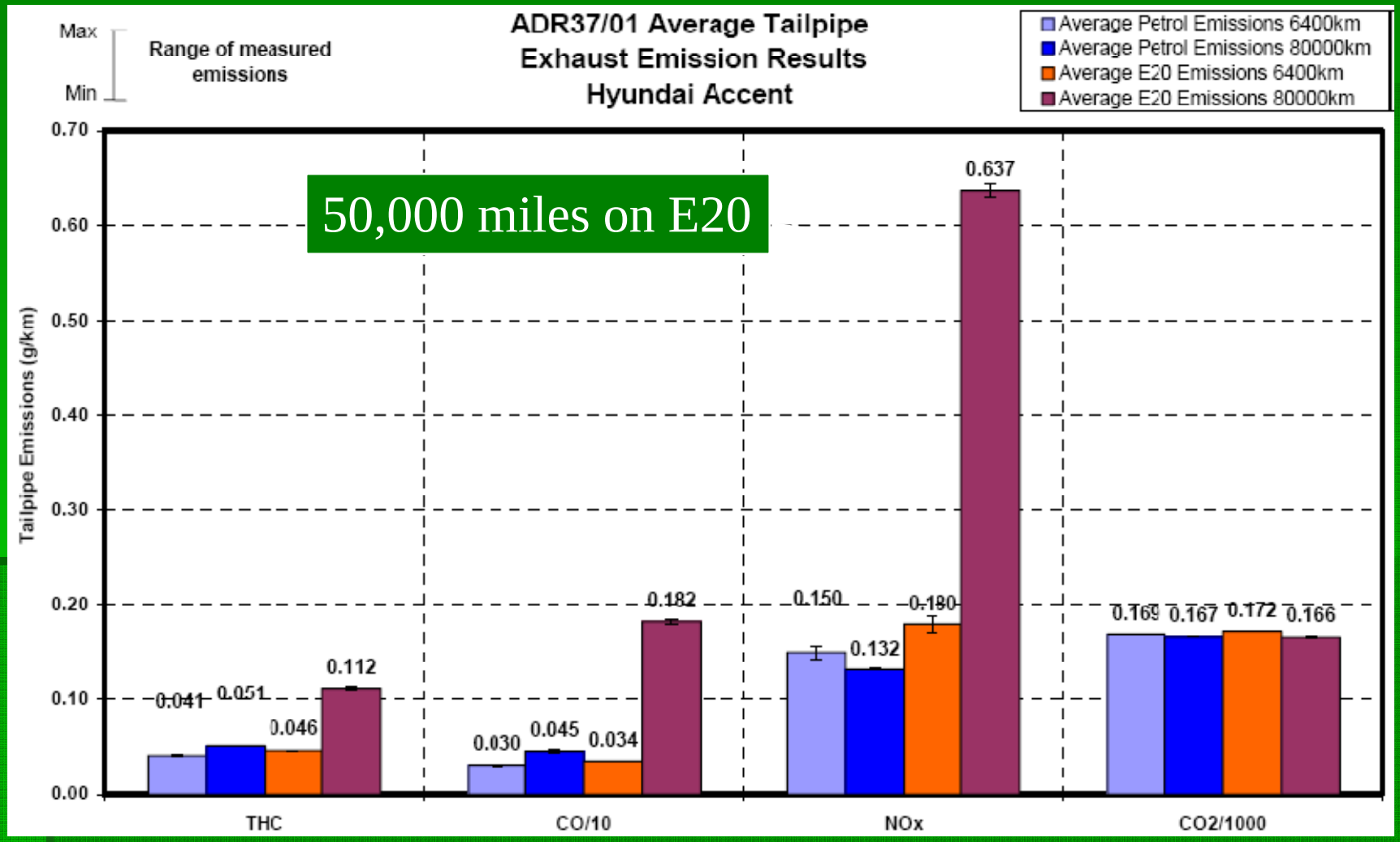
Cylinder head exhaust blow caused by high-combustion temperatures (courtesy: Briggs and Stratton).

Valve Failure Consequence

Hot exhaust valve with blow-by caused by high combustion temperatures (courtesy: Briggs and Stratton).

Failure Modes - 2

- Enleanment causes increased NOx emissions in many cases


ADR37/01 Average Tailpipe Exhaust Emission Results Hyundai Accent
Max
Min
Range of measured emissions
Average Petrol Emissions 6400km
Average Petrol Emissions 80000km
Average E20 Emissions 6400km
Average E20 Emissions 80000km
50,000 miles on E20
Tailpipe Emissions (g/km)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.041
0.051
0.046
0.112
0.030
0.045
0.034
0.182
0.150
0.132
0.180
0.637
0.169
0.167
0.172
0.166
THC
CO/10
NOx
CO2/1000

Failure Modes - 3

- Fuel tank materials degradation
  - Oligomers leach out of nylon
  - Leaks develop in fiberglass
  - Corrosion to steel tanks
  - Corrosion to zinc parts

Failure Modes - 4

- Elastomer seal ability degradation
  - Gaskets & o-rings swell losing seal
  - Fuel cap gaskets swell & block off tank venting, or fall out of fuel cap
  - Fuel hoses swell; and this reduces hose pull off force.

Fuel Caps and Gaskets

New and dry fuel caps and seals prior to fuel submersion testing (courtesy: Briggs and Stratton.)

Fuel Cap and Seal with E20

Fuel cap and seal assembly after a week's submersion into E20. Notice the bulging of the seal due to the extreme swelling of the gasket seal.

Failure Modes - 5

- Increased permeation relative to E0
  - Plastic (nylon, HDPE) tanks
  - Rubber fuel hoses

Failure Mode – 5 (contd.)

- Testing with gasoline (E0) and E10 by EPA shows:
  - 21-28% increase in permeation from HDPE tanks.
  - 20-70% increase in permeation from nylon tanks

Failure Mode - 6

- Plugged fuel filters & carburetors
  - For old equipment, gum & varnish built up in the fuel system will be loosened by E20, due to its higher solvency, causing filters & carburetor orifices to plug.

Other Failure Modes - 1

- Speed instability and audible speed hunting
- Poor load acceptance and sluggish acceleration
- Poor cold start
- Potential vapor lock
- Increased deposits in engine chamber

Other Failure Modes - 2

- Long Term Storage Issues
  - Increased water contamination due to E20 ability to hold water into solution. In turn, this increases corrosion & oxidation of fuel producing gum & acids
  - Formation of fungus & algae in fuel

Conclusions

- Use of >E10 fuel in products designed for <E10 fuels will likely:
  - Increase NO_x exhaust emissions
  - Increase HC evaporative emissions
  - Damage emission-related components (i.e., catalysts, cylinders, fuel lines and fuel tanks) causing increased emissions
  - Increase hazards to consumers (i.e., leaking fuels and greater heat) and also increase emissions due to leaks and fires
- Need additional studies on all the impacts on the diverse universe of both on-road and non-road engines, vehicles, boats and equipment, prior to making any regulatory changes.